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Hydrogen-Environment Embrittlement of Metals: A Study

High-pressure tanks and other metal structures used with hydrogen exhibit unpredicted failures. Even though the metal tanks are used well within their rated limits, the metals undergo a sharp reduction in fracture toughness. This phenomenon is known as hydrogen embrittlement, of which there are three categories:

1. Hydrogen chemical reactions, such as the reaction of hydrogen with interstitial oxygen in copper;
2. Internal hydrogen embrittlement, in which metal hydrides are formed within the structure; and
3. Hydrogen-environment embrittlement that takes place in a high-pressure hydrogen atmosphere when the metal is under stress.

The effects of hydrogen-environment embrittlement have not been well understood; they are the subject of an extensive study in which several research sources and projects have been critically evaluated, collated, and compiled.

The study includes extensive tests examining the effects of a hydrogen environment on different high-strength metals and alloys. The effects of such parameters as temperature, pressure, notch severity, hold time, and impurities are examined. These parameters are varied in a hydrogen environment, and the tested materials are examined for tensile properties, creep, fatigue, crack growth, and other evidences of embrittlement. In addition, the results of metallographic examinations of the hydrogen-damaged materials are presented.

Apparently a wide variety of metals and alloys are subject to hydrogen embrittlement. After an exposure to hydrogen at high pressures, surface embrittlement occurs with the first plastic deformation of the metal. The most significant effects are on tensile ductility, notch strength, and crack behavior. Several determining parameters are identified; it has been discovered that:

a. The degree of embrittlement increases with increasing rates of deformation;
b. The degree of embrittlement increases with hydrogen pressure;
c. The greatest effects occur at ambient temperatures; and
d. Exposure time does not affect the degree of embrittlement.

Recommendations for preventing metal failure include the use of hydrogen-resistant coatings and inhibitors. In addition, the study includes references to related investigations and a discussion of work in progress.

Note:

Requests for further information may be directed to:

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